

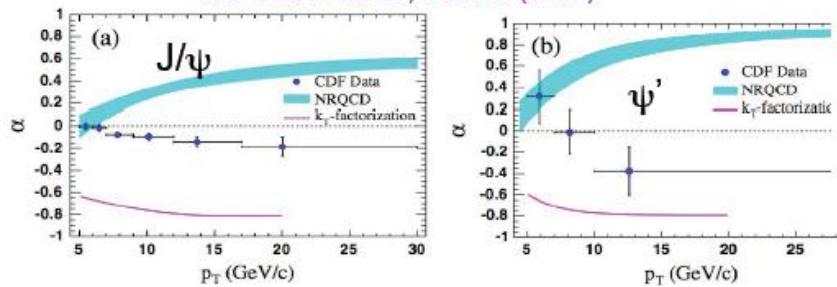
quarkonia production in PHENIX/RHIC in **pp** collisions

On behalf of the PHENIX collaboration

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Quarkonia: well known but often surprising

- In the last 15 years established picture of quarkonia production mechanisms have been often challenged by new experimental results
- Not yet back to a stable situation. For instance, Polarization, cross sections, P_T distributions, are difficult to reproduce simultaneously. Various models are considered: CSM, COM, CEM, ...
- perhaps this questioning (need for more universal description) could be extended, in p-A or A-A, to PDF use, or effects like shadowing.

Quarkonia production mechanism: overview in phenix

h-h and h-A heavy quarkonia production measurement at RHIC:

- characterize CNM (cold nuclear matter) effects thanks to pp and d-Au collisions in order to disentangle QGP effects in Au-Au collisions
- Use quarkonia for **probing production mechanisms in pp**, and also in high density (nucleus) and/or dynamical evolution (collision)
- Also: probing nucleon spin structure, or testing reaction symmetries, with polarized beams

Content

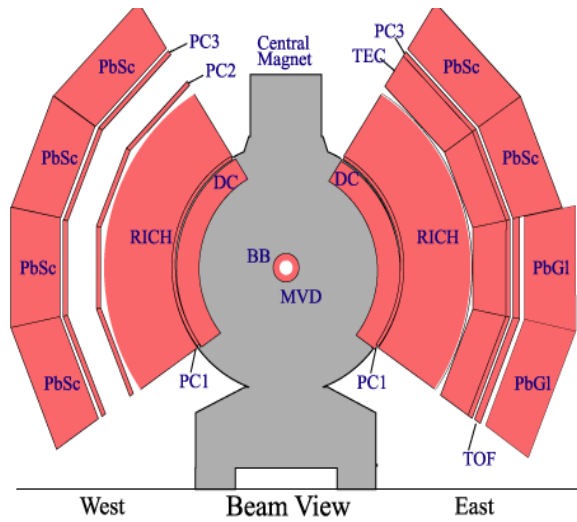
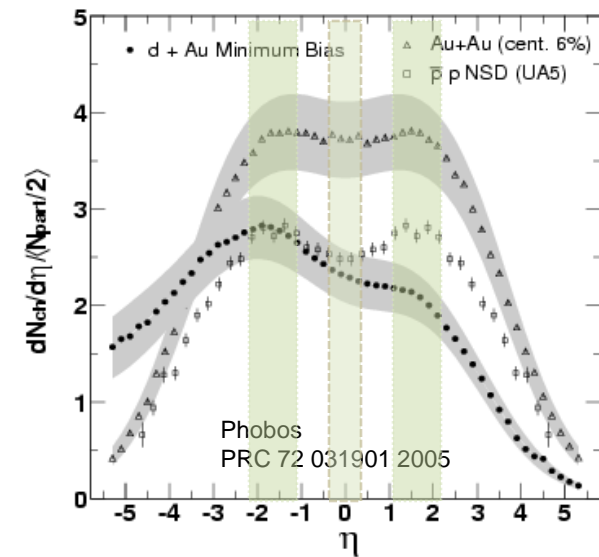
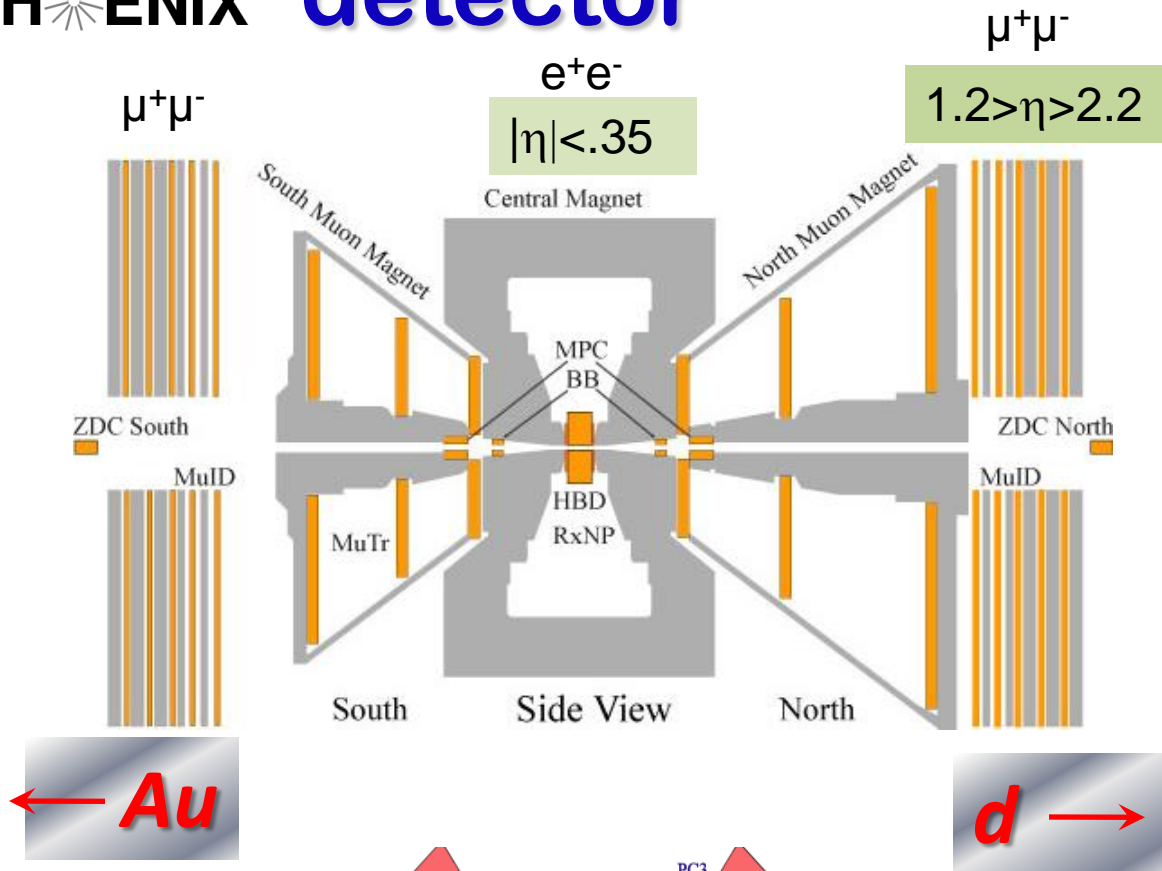
in pp collisions status of Υ , χ_c , J/Ψ polarisation, Ψ'

2006 p+p data with ~ 3 times previous (2005) luminosity !

Limited overview; does not adress:

- open flavour (single lepton, correlated e-h or μ production, ...)
- d-A, A-A results (H.Pereira's talk)

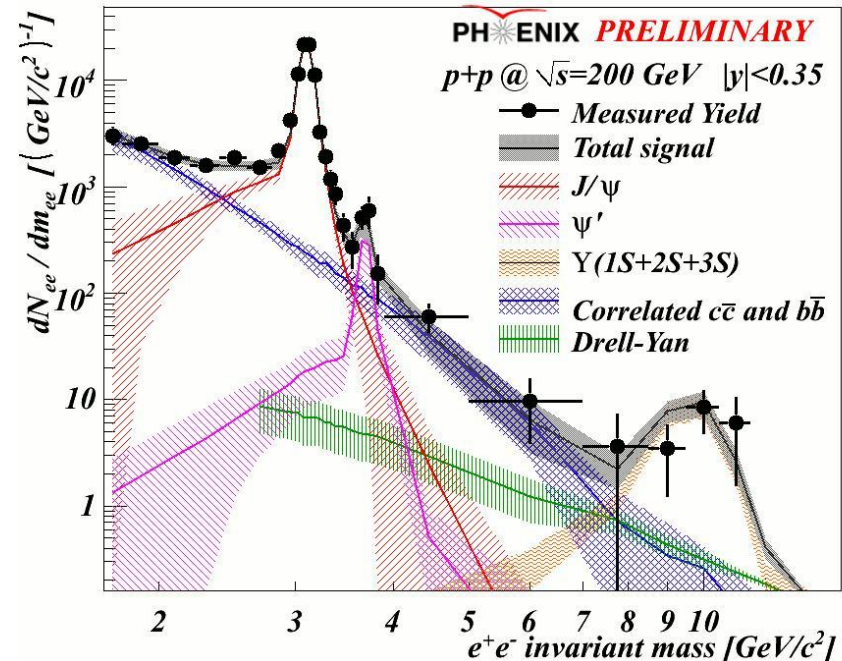
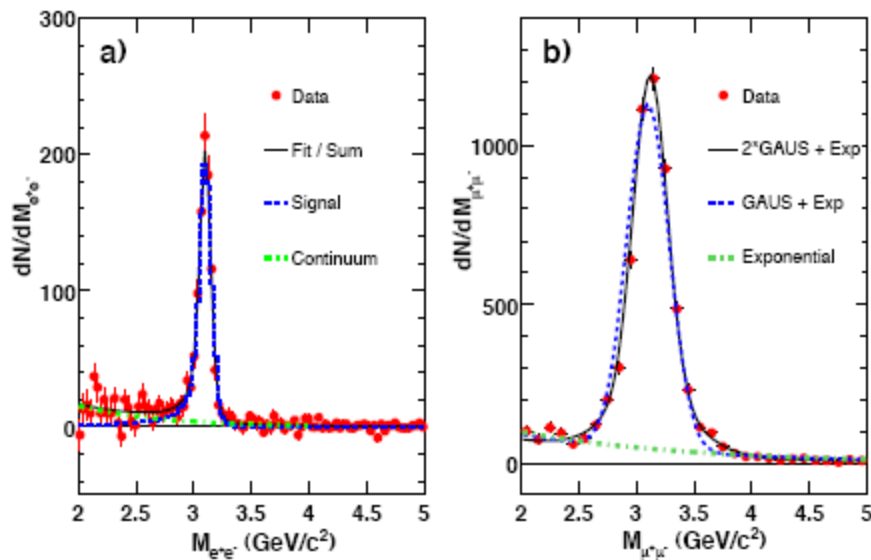
PHENIX detector



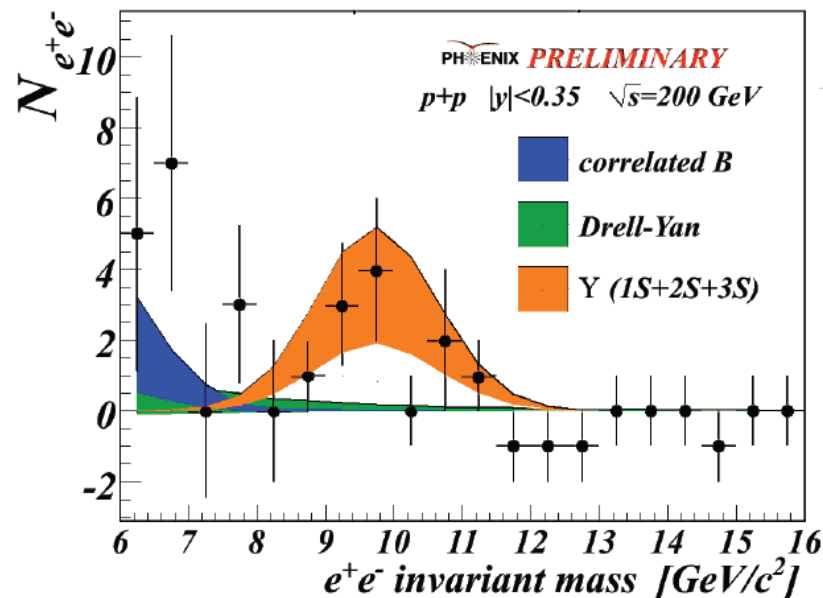
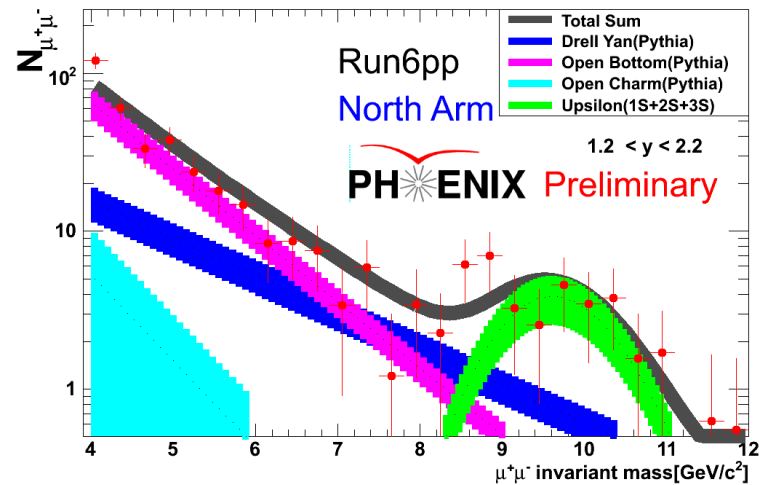
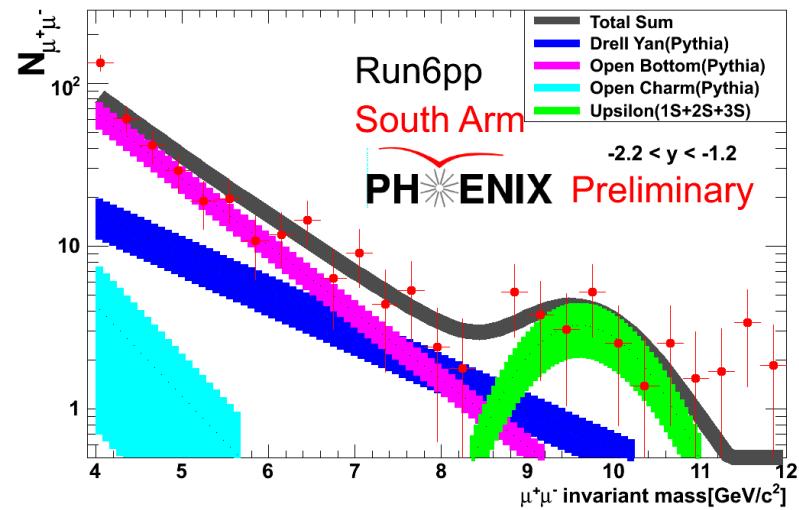
Energy in calorimeter
electron ID in RICH
Tracking in Drift chamber

Signal extraction

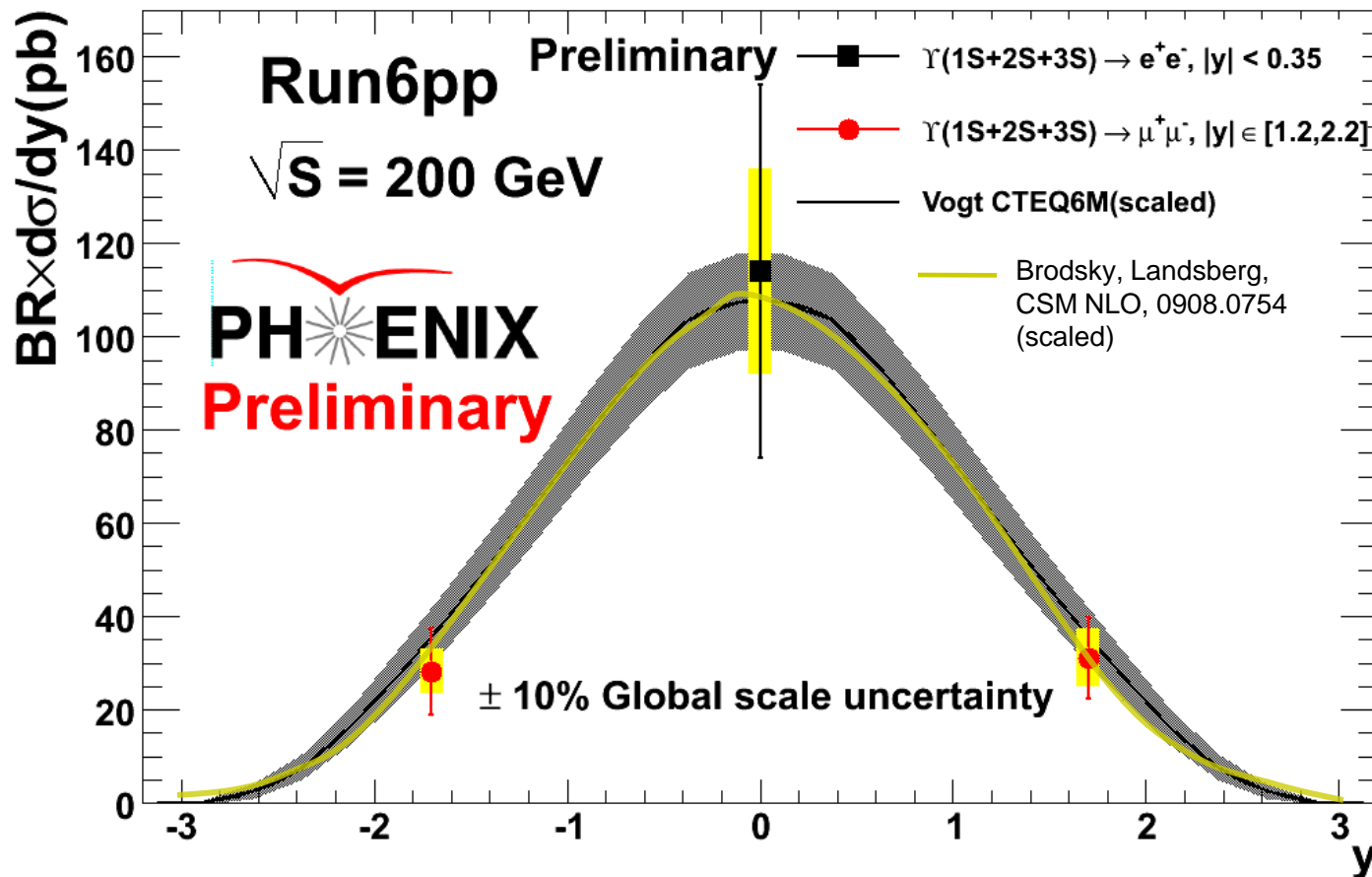
- **Pairs mass Continuum** (correlated « background ») : bb pairs , cc pairs, and Drell Yan
- **Uncorrelated Background pairs**: subtracted by mixed events techniques
- Fit with continuum and resonances components



Upsilon 1s+2s+3s in p-p



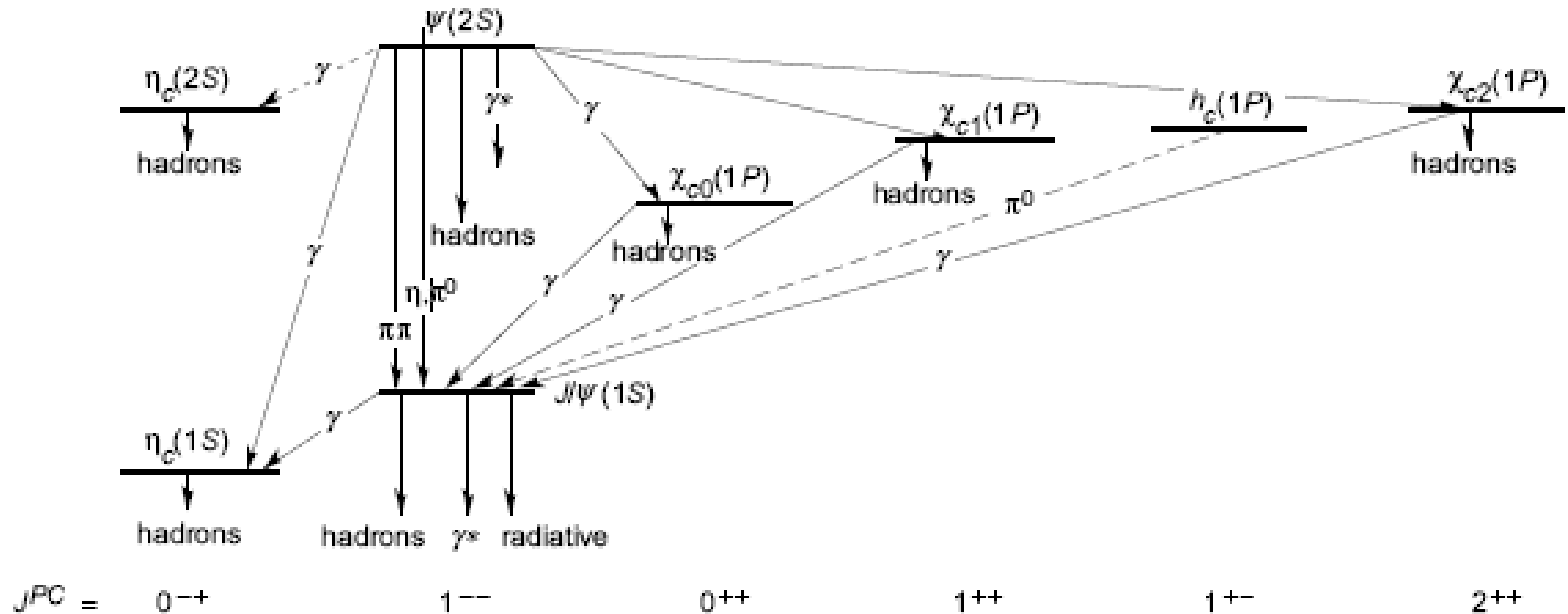
Upsilon cross section in p+p



$$BR^*d\sigma/dy = 28.2 \pm 9.4(\text{stat.}) \pm 4.8(\text{syst.}) \text{pb}, y \in [-2.2, -1.2]$$

$$BR^*d\sigma/dy = 31.1 \pm 8.7(\text{stat.}) \pm 6.2(\text{syst.}) \text{pb}, y \in [1.2, 2.2]$$

Charmonia



Heavy quarks pairs:

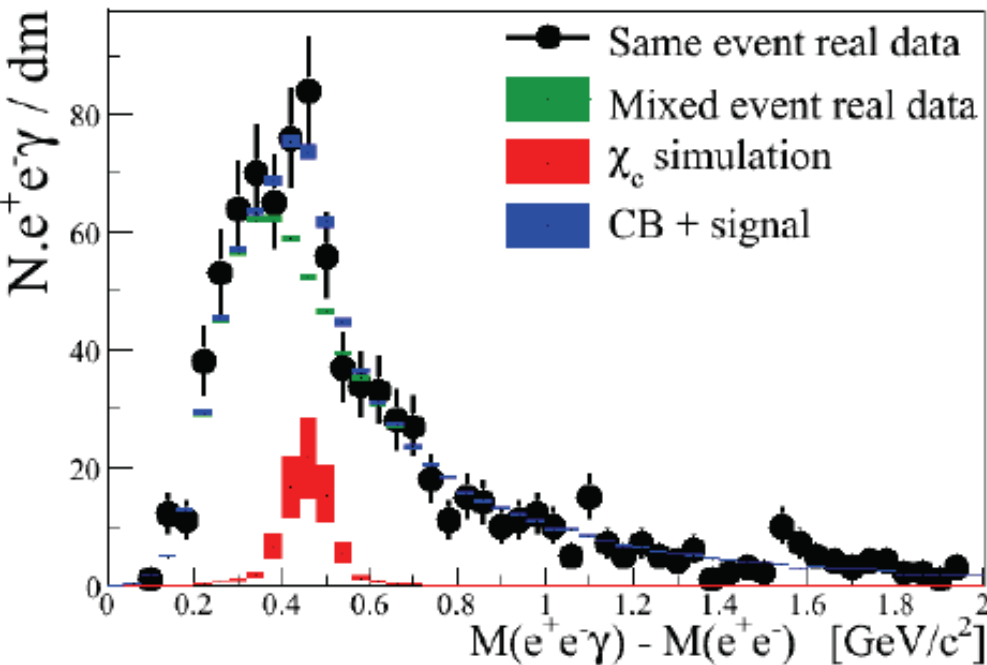
good probes: rare, weak light mesons coupling, various states and binding energies, non relativistic approximation

But

Feeding (also from open beauty)

χ_c

p-p 200 GeV



J/ψ from $\chi_c < 42\%$ (90% CL)

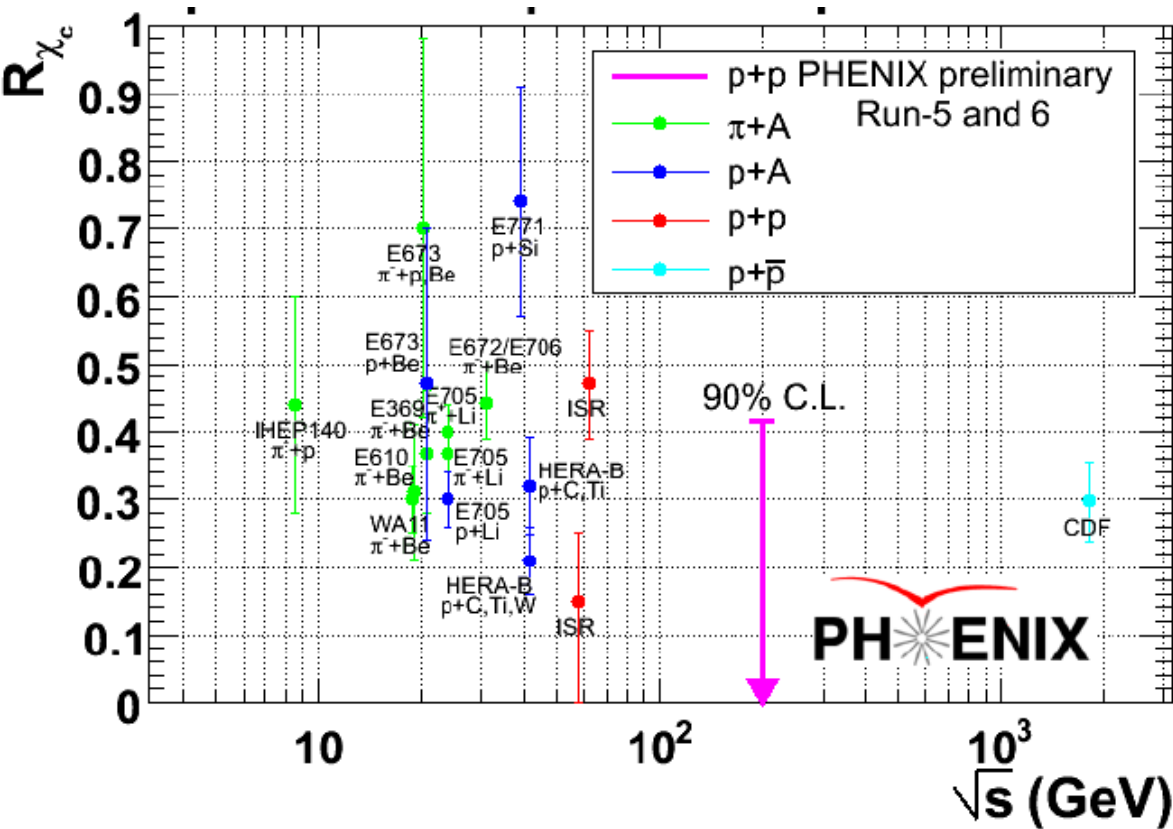
PHENIX preliminary

Measured at mid rapidity
via di-electron
+ photon in EMCal

Provides: feed-down contribution to J/ψ :

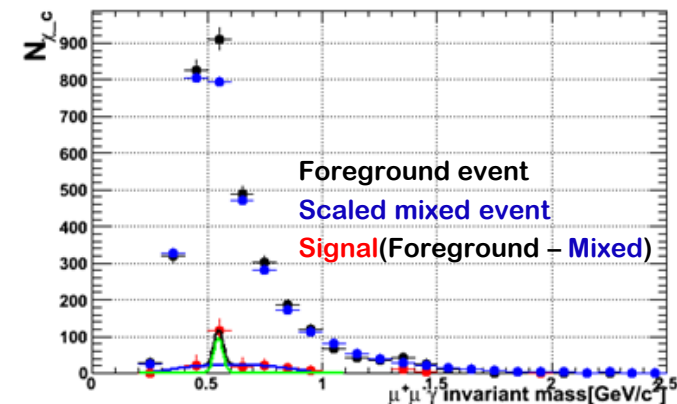
- Selection of J/Ψ mass dielectrons with a coincident photon
- Construction of Mixed event spectrum
- Extraction of photon peak

$$R_{\chi_c} = \frac{1}{\sigma(J/\psi)} \sum_{J=1}^2 \sigma(\chi_{cJ}) BR(\chi_{cJ} \rightarrow J/\psi \gamma)$$

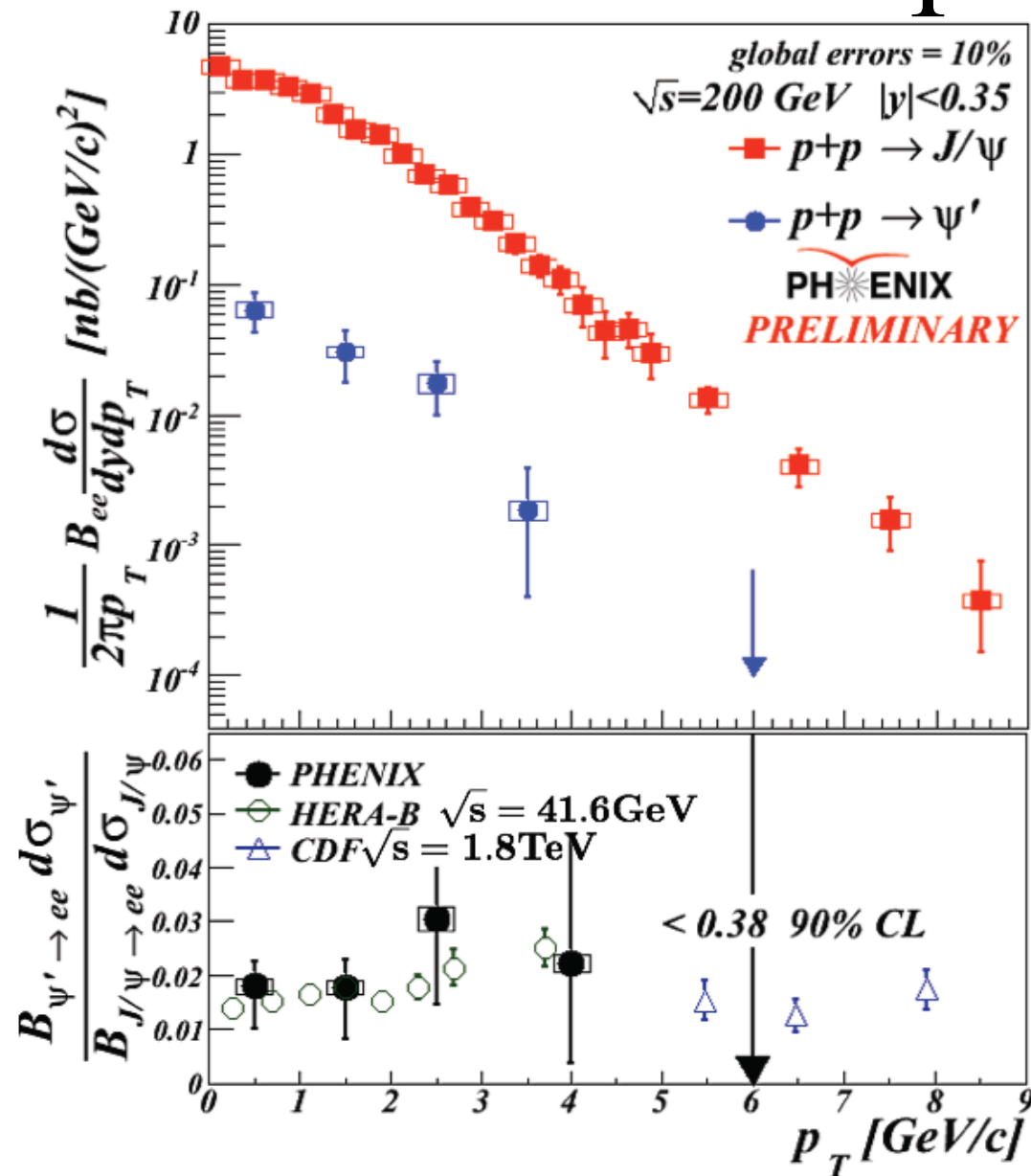


Near **future**: *forward* rapidity χ_c study in d-Au and p-p is under way

R_{χ_c} value is consistent with a recent selected average:
 $25 \pm 5 \%$
 (Faccioli JHEP 0810:004, 2008)



Ψ'



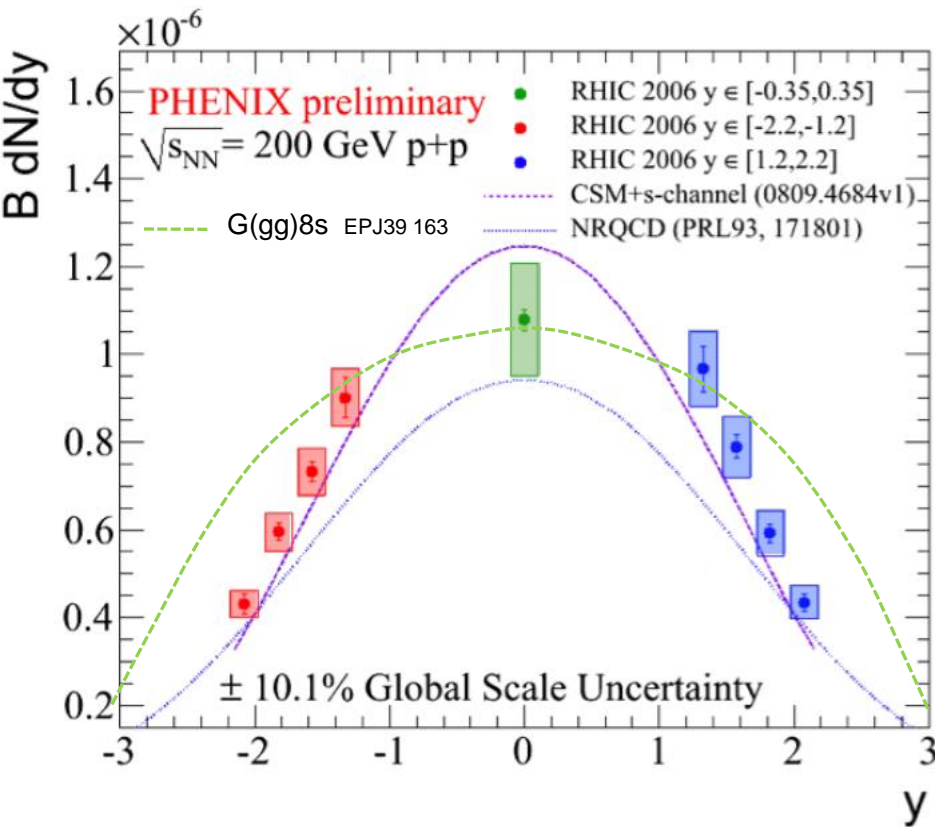
First measurement of Ψ'
transverse momentum
distribution at RHIC

Allows to estimate J/Ψ
feeding from Ψ' :
 $8.6 \pm 2.5 \%$

(world average $8.1 \pm 0.3 \%$ Faccioli JHEP
0810:004, 2008)

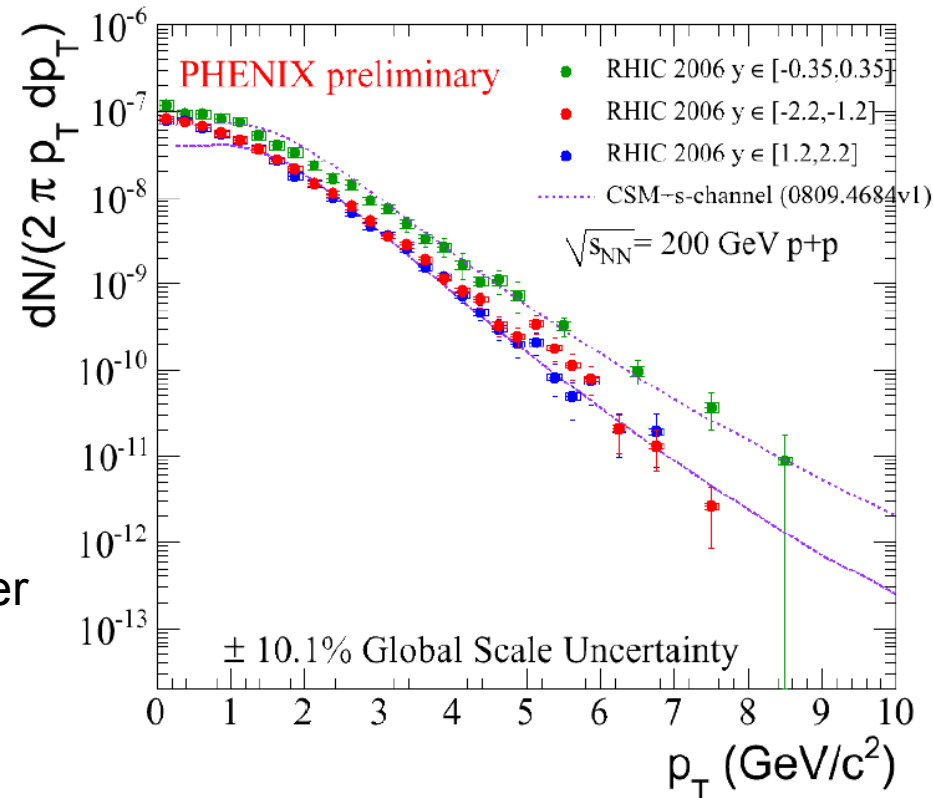
$\Psi'/(J/\Psi)$ Dielectron
production ratio:
in agreement with other
measurements, close to 2%

J/Ψ and production mechanisms



(COM (NRQCD) : only valid for $P_t > 2$ GeV/c)

The “s-channel cut” Color Singlet Model better reproduces the J/Ψ rapidity distribution
(Haberzettl, Lansberg, PRL 100 (2008) 032006)



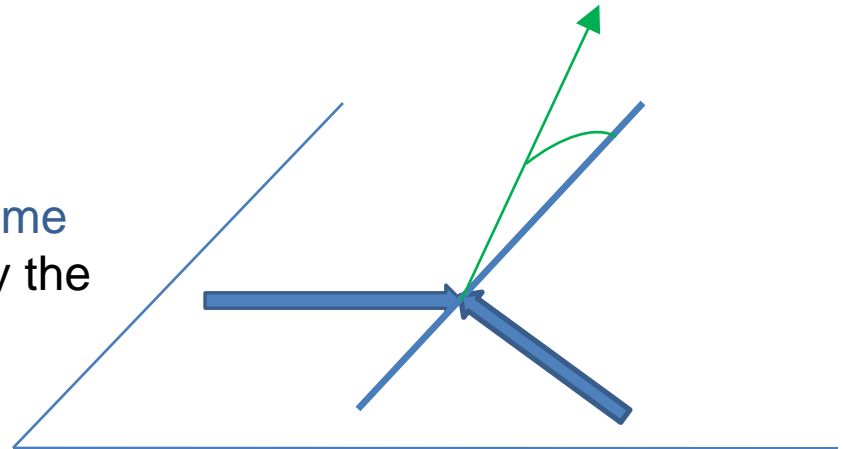
J/ψ polarization

$$\frac{dN}{d \cos \theta} = A(1 + \lambda \cos^2 \theta)$$

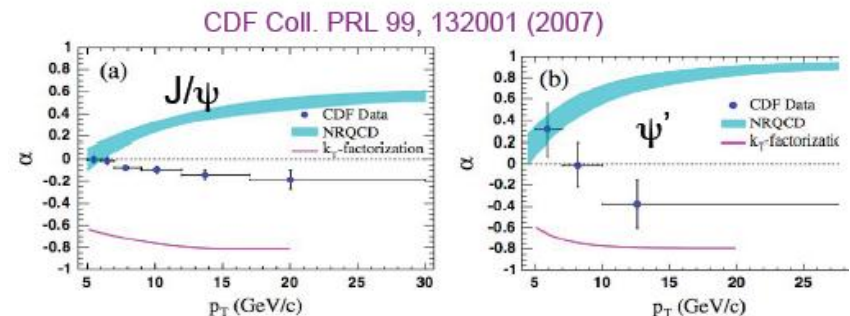
- $\lambda > 0$ transverse polarization
- $\lambda = 0$ no polarization
- $\lambda < 0$ longitudinal polarization

We use **helicity** frame

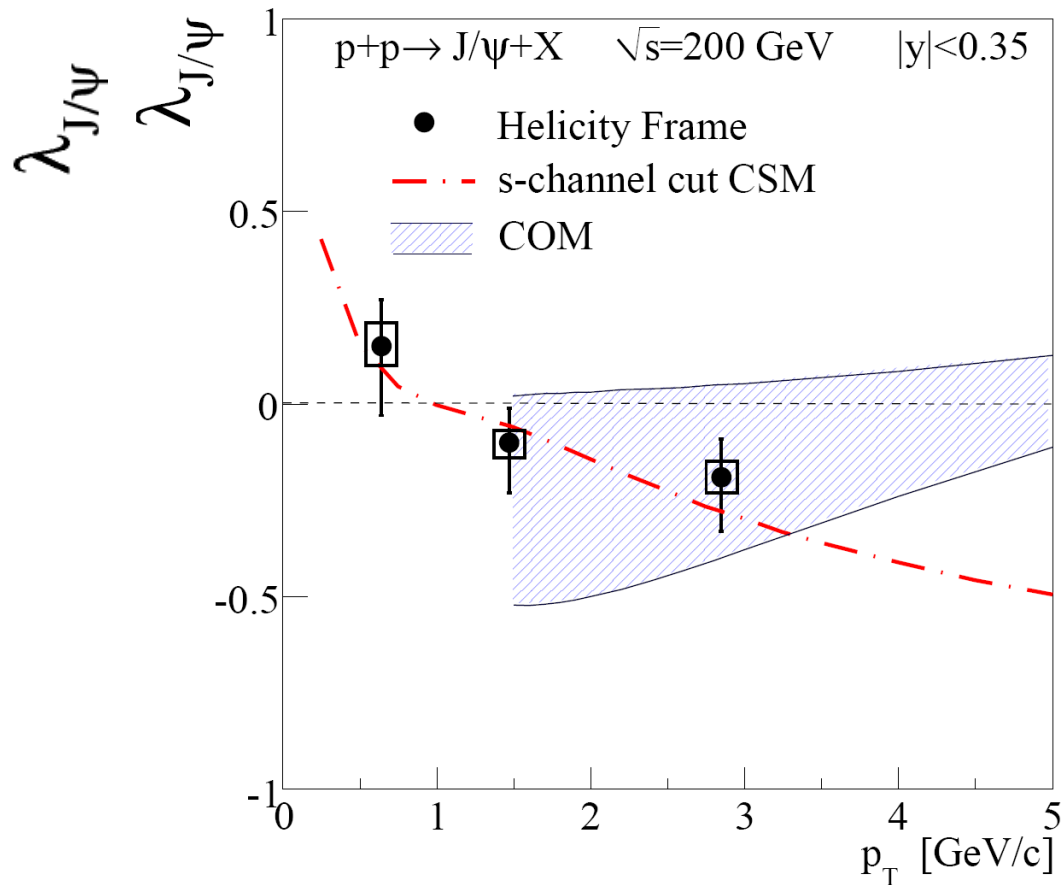
θ : decay **lepton angle** in J/ψ rest frame with respect to polar axis defined by the J/ψ momentum in colliding hadrons center of mass



⇒ J/ψ polarization measurement provides a powerful discriminating tool between models



J/ψ polarization



New extended results are under way

→ In the forward region

- Measurement performed in *helicity* frame
- Contains feeding

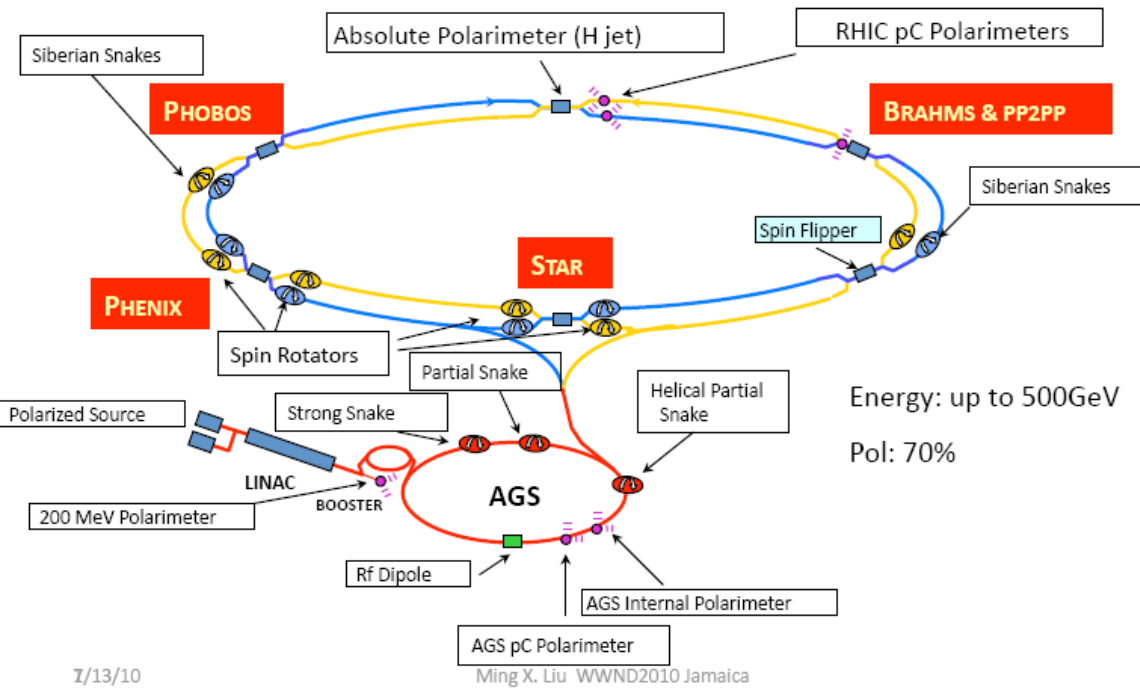
Polarization: crucial test for the production mechanism.

will these results allow to discriminate between CSM + S channel cut and CEM models ?

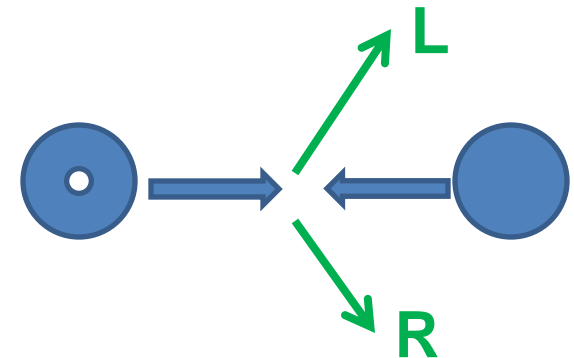
(COM not suited for low p_T range, but in agreement for 2 highest P_T points)

Chung et al. PRD81 014020 2010

RHIC Polarized Proton Collider



$$A_N = \frac{1}{P} \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R}$$



Measuring
quarkonia production asymmetries
with polarized beams

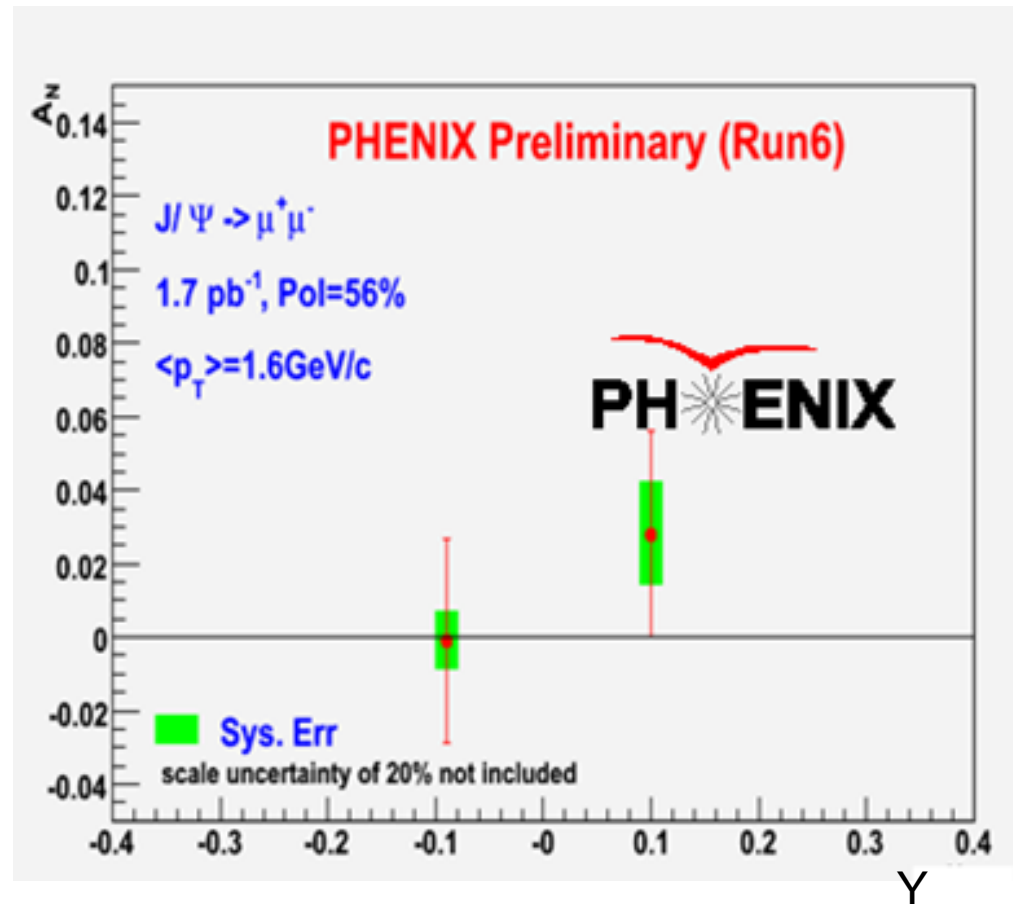
- Quarkonia transverse asymmetry production
- if linked to transverse momentum dependent distributions of partons
- Sensitive to production mechanism:
Yuan PRD 78 :014024,2008
Vanishing asymmetry :
in **ep in color singlet** model
in **pp in color octet** model

First measurement of A_N in heavy vector meson J/Ψ production

A new way of testing the J/Ψ
production mechanism

An exploratory measurement
(final results under way)

more data needed on pp.
ep also needed



summary

An improving set of informations from PHENIX experiment in pp collisions should help to progress on the understanding of quarkonia production mechanisms:

- upsilon production, continuum subtracted, along 4 units of rapidity. Υ shape consistent with CEM and CSM NLO calculations.
- Increased precision in J/Ψ Υ and P_t distributions: agreement with CSM+S channel cut calculations
- Ψ' and χ_c production and J/Ψ Side feeding knowledge
- new results under way: forward χ_c and J/Ψ polarisation
- First preliminary analysis of J/Ψ prod. with polarized beams

- Cold and hot matter effects also open complementary dimensions

Future directions

- Available data from 2009 pp 200 GeV and 500 GeV runs with increased statistic
- Forward (muon arm - MPC) extraction of χ_c under way, + FOrward CALorimeter project
- B- \rightarrow J/ Ψ +X with SVTX (>2011)
- Resolve Ψ' in muon arms thanks to FVTX (>2012)